derstand, or that I had not the true inspiration, as, certainly, they paid not the slightest regard to the notice to quit which I then gave them.

"Martin, in his Tour to the Western Isles, says, that the ancient race of the Island of Rona was, about the year 1700, all destroyed in the following manner:—First, a swarm of rats, none knows how, came into the island and eat up all the corn. In the next place, some seamen landed and robbed them (the people) of what provisions they had left, and all died before the usual time of the arrival of the boat from Lewis."

The President read a paper on the probable errors of the eye and ear in transit observations.

"Among the important applications of the Electric Telegraph which every day is producing, none is more interesting to those who pursue physical inquiries than its power of making time-determinations with a precision and facility which promise ere long to supersede the existing processes. In its very first application to determine longitudes by making the clock of each station beat its time at the other, its immeasurable superiority was at once revealed; and though it has not been as completely established in the more ordinary operations of the Observatory, yet that is only an affair of a few years. One of these seems specially to invite it,—the determination of right ascension; and already Mitchel and, I believe, others have obtained results which appear to surpass those hitherto obtained by the transit instrument.

"The principle is this: the clock, by a well-known apparatus, prints on some fit surface a series of equidistant dots by the successive vibrations of its pendulum. Between any pair of these the observer can interpose a dot at the instant of a phenomenon, and its place, with respect to them, gives the time. This reduction can be made at leisure, as the record is permanent, and a scale of any reasonable magnitude can be

given to the second. The American astronomers have compared the results of this method with the Greenwich transit observations, and have found, in the words of Mr. Airy, that 'the measure of its irregularities is only about one-fourth of that of the other.' He, however, very truly remarks that 'a portion of these differences may be owing to the difference in the state of the atmosphere, that of England being perhaps comparatively unfavourable to accurate observations.'

"In making a comparison of this kind it must be remembered that the two systems not merely employ different senses to co-operate with sight, but that the sight itself is used in two different ways. In the 'Electric Register' the eye catches the moment when the star crosses a wire, and the touch is to synchronize with it in giving a signal. In the common modes the ear counts the clock's beats; the eye notes the distances of the star from the wire at the beats which precede and follow its passage, and thus the mind estimates the fraction of the second from the relative position of three points; all existing *in memory alone* when that estimation is made. Now this is rather a complicated operation; and it is evident that the optical part of it must be much more liable to uncertainty than the mere noting the occurrence of the transit. Of this latter, as well as of the relative promptitude of hearing and touch, it is desirable to have careful determinations; but if any such have been made during the five years that have elapsed since this new principle of observation was discovered, they have not reached me. In hopes, therefore, of drawing attention to the subject, I offer to the Academy the results of a similar examination, applied to the Armagh Transit Observations, for the purpose of ascertaining how far they could be improved, and what probable weights should be given to certain elements of reduction.

"The error which may be caused by uncertainty in catching the precise part of the beat which shall be taken for the origin of the second, is the same for every star (at least if we

suppose the clock equally audible in every position of the telescope, and the observer able to observe in all with equal convenience, for personal discomfort will interfere with the attention). That arising from uncertainty in estimating the star's place will vary inversely as the cosine of its declination.

" But there is yet another, arising from the actual displacement of the star's image, by irregular changes in the refractive density of the atmosphere; the effect will, as the preceding, be inversely as the cosine of declination, but also directly as the magnitude of these changes. This depends, in the first place, on the heterogeneity of the air as to heat and moisture; and in the second, on the quantity of disturbed medium through which the line of sight passes. The former scarcely admits of expression in terms of our present meteorological data, and we must be content to assume for it an average value. In respect to the other, as the disturbance takes place chiefly within a small distance of the earth's surface, it will easily be seen that its amount is as the secant of zenith distance. If then we denote by u the probable error of the ear, by y that of the eye, and by z the atmospheric tremor at the zenith, we have, by the theory of these errors, for a star whose declination is δ,

$$\varepsilon^2 = u^2 + \frac{y^2}{\cos^2 . \delta} + \frac{z^2}{\cos^2 \delta \, . \cos^2 (l - \delta)}.$$

It is evident that z admits of a minimum in respect of δ: let x be the tangent of $l - \delta$, λ that of latitude, and $r = \frac{z}{y}$, differentiating and equating to 0, we derive

$$x^4 + \frac{2}{\lambda} x^3 + \frac{2r^2 + 1}{\lambda r^2} - \frac{r^2 + 1}{r^2} = 0.$$

" If then we select three stars, properly differing in zenith distance, we can determine the three errors u, y, and z. We find ε in the usual way, by comparing each wire of a set of n

with its mean; but as this mean is itself affected with an error $= \frac{\varepsilon}{\sqrt{n}}$, the value thus computed must be multiplied by

$$\sqrt{\left(\frac{n}{n+1}\right)}.$$

"My first examination was made in 1830. The instrument had then seven wires, and its eye-piece gave a power of 130. It was, however, far inferior in sharpness of definition to the one which it replaced; that was 104, and was removed because it was unprovided with means of attaching a dark glass for sun observations.

"The stars chosen, observed almost in every case on the same nights, except the excess of the second, were

α Lyra,	$\delta = + 38°.38'$ . . .	No. wires, 120
β Aquilæ,	$+ 5°.59'$ . . .	,, ,, 167
α^2 ♑	$- 13°.4'$ . . .	,, ,, 122

Giving the equations

$$(0^s{\cdot}1041)^2 = u^2 + y^2 \times 1{\cdot}63878 + z^2 \times 1{\cdot}76856$$
$$(0^s{\cdot}0959)^2 = u^2 + y^2 \times 1{\cdot}01097 + z^2 \times 2{\cdot}29065$$
$$(0^s{\cdot}1281)^2 = u^2 + y^2 \times 1{\cdot}05385 + z^2 \times 7{\cdot}14595$$

These give

$$u = \pm\, 0^s{\cdot}\, 0445; \quad y = \pm\, 0^s{\cdot}0619; \quad z = \pm\, 0^s{\cdot}0381.$$

In my case, therefore, the ear could estimate the twenty-third part of a second, and its precision was to that of the eye as 7 : 5.

"With this ratio of y to z, the two real roots of the equation of minimum are, the positive = tang. 37°. 55′; and the negative (belonging to a sub-polar transit) = tang. 66°. 47′. Therefore, stars passing at those zenith distances should be used at Armagh to obtain the exactest determination of time. In such an examination we must be careful to use observations made under conditions as nearly the same as possible. For instance, they must be all day or all night ones, as the

errors are very different in these cases; the first being at this Observatory to the second as 4 to 5; and I even think the stars ought not to differ in magnitude or colour: but if these precautions be attended to, I am satisfied that very exact conclusions may be attained. Perhaps no stronger evidence of this can be given than the result of a second examination, instituted several years after certain alterations had been made in consequence of the first one.

"As the value of y was not very much less than the whole ε that I had obtained with the former eye-piece, notwithstanding its low power, a new one was obtained from the late Mr. Dollond, of 240, and very good. Nine lines were inserted by Mr. Grubb, finer and more uniform than the previous seven; the clock, whose arc of repose had been four times that of escape, had its weight changed from 4 lbs. to 1·75; and a multitude of trees and shrubs were removed from the south of the transit-room, as their evaporation was a manifest cause of unsteadiness. All these, except the alteration of the clock, tended to lessen the error; that improved the rate, but it made the beat less audible in high winds, and therefore would increase u.

"In this instance stars all of the first magnitude were selected; one of them, Fomalhout, I had formerly been unable to use on account of its excessive fluctuations. They were

α Lyra,	$\delta = +\ 38^\circ.\ 39'$ . . .	No. wires,		279
α Aquilæ,	$+\ 8^\circ.\ 29'$ . . .	,,	,,	251
Fomalhout,	$-\ 30^\circ.\ 27'$ . . .	,,	,,	278

Giving

$$(0^s{\cdot}1022)^2 = u^2 + y^2 \times 1{\cdot}63955 + z^2 \times 1{\cdot}76909$$
$$(0^s{\cdot}0925)^2 = u^2 + y^2 \times 1{\cdot}02225 + z^2 \times 2{\cdot}10826$$
$$(0^s{\cdot}1162)^2 = u^2 + y^2 \times 1{\cdot}34559 + z^2 \times 163{\cdot}81153$$

Whence

$$u = \pm\ 0^s{\cdot}0732;\quad y = \pm\ 0^s{\cdot}0554;\quad z = \pm\ 0^s{\cdot}0049.$$

The error of hearing is considerably increased; that of sight a little lessened, but the tremor is only a seventh part of its original amount.

"It is evident that the same equations apply to the new mode of observation if u represent the error of touch; and it is to be hoped that a similar discussion of its probable errors may be soon instituted, for there are a number of inquiries which must be answered before its superiority will be fully appreciated. Independent of the possibility that the means employed to close and break the voltaic circuit may disturb the clock's pendulum, and that the promptness of the register may vary with the intensity of the battery, it is certain that in the obedience of the finger to the will there must be a personal equation, and it is possible that this, unlike that of the ordinary transit observer, may be variable. For any regular succession it will probably be insensible, as I infer from some observations given by Mr. Mallet in the report of his valuable experiments on the propagation of Earthquake Waves, p. 306. Starting a chronograph at a given beat of a clock, and stopping it at another, he gives the differences from the mean, whence I compute ε, for himself $= \pm\ 0^{s}{\cdot}0449$, and for his son $\pm\ 0^{s}{\cdot}0592$. Each of these involves two errors of ear and two of finger, so that the measure of one of each is $0^{s}{\cdot}0318$ and $0^{s}{\cdot}0419$. These come so near my u, that any error of touch is scarcely possible; the case is, however, a special one, and may be compared to the counting seconds without a clock, which a practised observer will do with surprising accuracy. Phenomena not regularly recurring could scarcely be taken so accurately.

"The error of sight will, for the reason already given, be less in the case of stars; as to the sun and moon, it is more doubtful. In the transit they have larger probable errors than the stars. For the sun I obtained in 1830 the first limb $\pm\ 0^{s}{\cdot}116$, the second $\pm\ 0^{s}{\cdot}087$; the moon gave $\pm\ 0^{s}{\cdot}149$; while stars observed at the same hour, and near the same parallel,

had but $\pm 0^{s}\cdot097$. This greater uncertainty arises from the strong contrast between the bright and dark surfaces whose boundary we take; and a similar one may be expected in attempting to note the precise instant of its passage.

"As to tremor, it will act here precisely as in transit observations, and it may, moreover, perhaps nullify one of the proposed advantages, that of making many observations in a few seconds. The undulations of the air are twofold, those of short period, which cause the flutter that produces z, and those of much longer duration, which, without blurring the star, displace it, and sometimes cause the pole-star, after crossing a wire, to go back, and after ten or even fifteen seconds make a second transit. In the present mode such waves affect only a single wire, and may be neutralized by others; but in the other they would vitiate the whole set.

"I mention these doubts in the hope that some of our own astronomers may take up the subject, and examine it fully. If there be practical objections to it they may be remedied; but if it really possess the advantages which it seems to have, it should be decidedly adopted. At all events it is a step in the right direction, for we have now carried the existing processes and instruments of astronomical research nearly as far as they can go, and new powers must be invoked, if we wish to make further progress."